BLOOD COMPONENTS SEPARATOR DISK

TECHNICAL FIELD

This invention relates to methods and apparatus for use in the separation of fluids into components having different specific gravities. The invention finds particular utility in the centrifugal separation of the components of blood.

BACKGROUND

Centrifugal separation of blood into components of different specific gravities, such as red blood cells, white blood cells, platelets, and plasma is known from United States Patent 5,707,331 (Wells). The apparatus shown in that patent employs a disposable processing tube having two chambers, and blood to be separated into components is placed in one of the chambers. The processing tube is placed in a centrifuge, which subjects the blood to centrifugal forces to separate the components. The supernatant is then automatically decanted into the second of the chambers.

To retain, principally, the red blood cells during the decant of the supernatant, the apparatus disclosed in the Wells patent includes a shelf placed in the first chamber at the expected level of the interface between the red blood cells and the less-dense components, including the plasma. One problem with the arrangement shown in the '331 Wells patent, however, is that the position of the interface varies with the particular proportions of the components (e.g., the hematocrit) of the blood to be processed. Thus, if the

shelf is placed at the expected position of the interface for blood of average hematocrit, and the hematocrit of the particular blood being processed is low, the shelf will be above the interface after separation. Such a position of the shelf will hinder the flow of the components near the interface during decanting, thus retaining significant amounts of these components in the first chamber and reducing the separation efficiency of the system.

SUMMARY OF THE INVENTION

In accordance with the invention, a movable separator disk, which automatically positions itself at the interface between the separated components, is placed in the first chamber. In the preferred embodiment, the disk is capable of moving vertically and is designed to position itself automatically at the interface between red blood cells and the remaining components in the centrifugal separation of blood.

Decant of the supernatant can be either by gravity drain or by centrifugal transfer, and a main function of the disk is to restrict the flow of the component below it, e.g., red blood cells, during decant. This ensures that the supernatant is not contaminated and increases the efficiency of the process.

The invention contemplates two embodiments for the disk. In one embodiment, the disk is supported on a central shaft such that an annulus is formed between the perimeter of the disk and the interior surface of the first chamber. The dimensions of the annulus are such that the flow of red blood cells through it during decant is restricted such that they do not contaminate the decanted supernatant to any significant degree.

In another embodiment, the disk is arranged on the shaft such that, when the chamber is tilted for gravity decanting, the disk rotates such that one edge of the disk engages the wall of the chamber to block flow of red blood cells.

In either of these embodiments, the specific gravity of the disk and its shape may be chosen so that a major part of the upper surface lies just below the interface, thus facilitating release of the supernatant from the disk during decanting. This upper surface is also preferably curved to match the cylindrical shape the interface assumes during centrifugation.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1a is a longitudinal cross-section of a portion of a processing tube chamber and a separator disk in accordance with a first embodiment of the invention.

Figure 1b is a transverse cross section taken along line 1b-1b of figure 1a.

Figure 2a is a longitudinal cross-section of the embodiment of figures 1a and 1b when the separator disk is tilted during decanting.

Figure 2b is a transverse cross section taken along line 2b-2b of figure 2a.

Figure 3a is a longitudinal cross-section of a second embodiment of the invention.

Figure 3b is a transverse cross section taken along line 3b-3b of figure 3a.

Figure 4 is a longitudinal cross-section of a third embodiment of the invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

With reference to figures 1 and 2, one chamber 2 of a processing tube. such as that shown in the '331 Wells patent has a separator disk 4 in accordance with the invention supported therein by a central shaft 6. The shaft 6 is designed to direct fluid introduced into the chamber to the bottom of the chamber. This precludes the formation of an air bubble at the bottom of the chamber, particularly when the bottom of the chamber is tapered. Thus, fluid is introduced into the chamber by inserting a cannula attached to a syringe containing blood into the shaft 6 and discharging the blood from the syringe into the chamber. A central opening 8 in the disk receives the shaft 6 in such a manner that the disk easily slides along the shaft.

The shaft 6 may not be necessary in all instances, for example, when the bottom of the processing tube is flat. In that instance the disk does not have a central hole.

The disk is preferably made of material having a specific gravity that allows the disk to float at the interface with red blood cells. In the preferred embodiment that specific gravity is about 1.04 (e.g., polystyrene), which is just less than the specific gravity of red blood cells at 70% hematocrit. Thus, when the blood is centrifuged, the disk moves to the interface between the red blood cells and the other components.

The interface will naturally assume a cylindrical shape with a cylindrical radius equal to the distance to the center of rotation of the centrifuge. The disk may be cylindrical, to match the shape of the interface.

In the embodiment shown in figures 1a, 1b, 2a and 2b, the diameters of the hole 8 and the shaft 6 are such that an annular gap 10 is formed between

the outer surface of the shaft and the interior surface of the hole 8. Similarly, an annular gap 12 is provided between the perimeter of the disk and the interior surface of the tube 2.

Figures 1a and 1b illustrate the position of the disk during centrifugation, and it will be appreciated that the gaps 10 and 12 are large enough to allow passage of the descending heavier components, e.g., red blood cells and the ascending lighter components, e.g., plasma. According to this embodiment, however, the diameter of the central opening 8 is large enough whereby during decanting the disk 4 rotates as shown in the figures. Thus, when the processing tube is rotated to the decant position, the more dense red blood cells, illustrated at 14, that have accumulated below the disk exert a force against the bottom of the disk as they try to flow through the gap 12. This causes the disk 4 to rotate, as shown in figures 2a and 2b, until a portion of the lower outer edge 16 of the disk and also the upper outer edge 18 engage the inner surface of the chamber 2. This engagement between the edge 16 of the disk and the interior of the chamber effectively forms a valve that prevents flow of the red blood cells, allowing decant of the plasma supernatant without contamination by red blood cells. It will be appreciated that this embodiment requires the transverse dimension of the disk between edges 16 and 18 to be greater than the internal diameter of the tube so that the edges engage the interior of the tube when tilted.

A second embodiment is shown in figures 3a and 3b. According to this embodiment, the gap 10 is made to be small whereby the disk does not rotate appreciably during decant, in contrast to the embodiment of figures 1 and 2. It will be appreciated that an annular channel is formed by the gap 12, this

channel having a width equal to the radial dimension of the gap and a length equal to the thickness of the disk at the edge. The rate of flow of a fluid through this channel is a function of the dimensions of the channel, and the dimensions of the disk of this embodiment are such that the red blood cells will not flow appreciably through the channel at 1G. In the preferred embodiment, the width of the gap is about 0.005 inch to about 0.020 inch, and the length is about 0.1 inch to about 0.3 inch.

Thus, the components of the blood flow through the channel during centrifugation (i.e., at 1000G), but do not flow appreciably through the channel during decanting at 1G. This allows the supernatant to be decanted without significant contamination by the red blood cells.

Figure 4 illustrates a preferred shape of the disk 4. In this embodiment, the top surface 20 of the disk is concave, preferably cylindrical, and the disk is provided with an elongated central portion 22. The specific gravity of the disk material is selected so that the concave surface 20 is located just below the interface. That is, the thickness of the outer edge, the length of the portion 22, and the specific gravity of the material are chosen so that the center of buoyancy of the disk is just above the concave surface, and that surface will be just below the interface 26 with red blood cells. This arrangement allows a small layer 24 of the red blood cells to form on the upper surface.

The layer of red blood cells 24 reduces the surface tension between the platelets at the interface 26 and the surface 20 of the disk and facilitates release of the platelets from the disk. This is important to ensure that all of the platelets are decanted, and the small amount of red blood cells that may

be decanted along with the supernatant does not generally represent a significant contamination of the supernatant.

Modifications within the scope of the appended claims will be apparent to those of skill in the art.